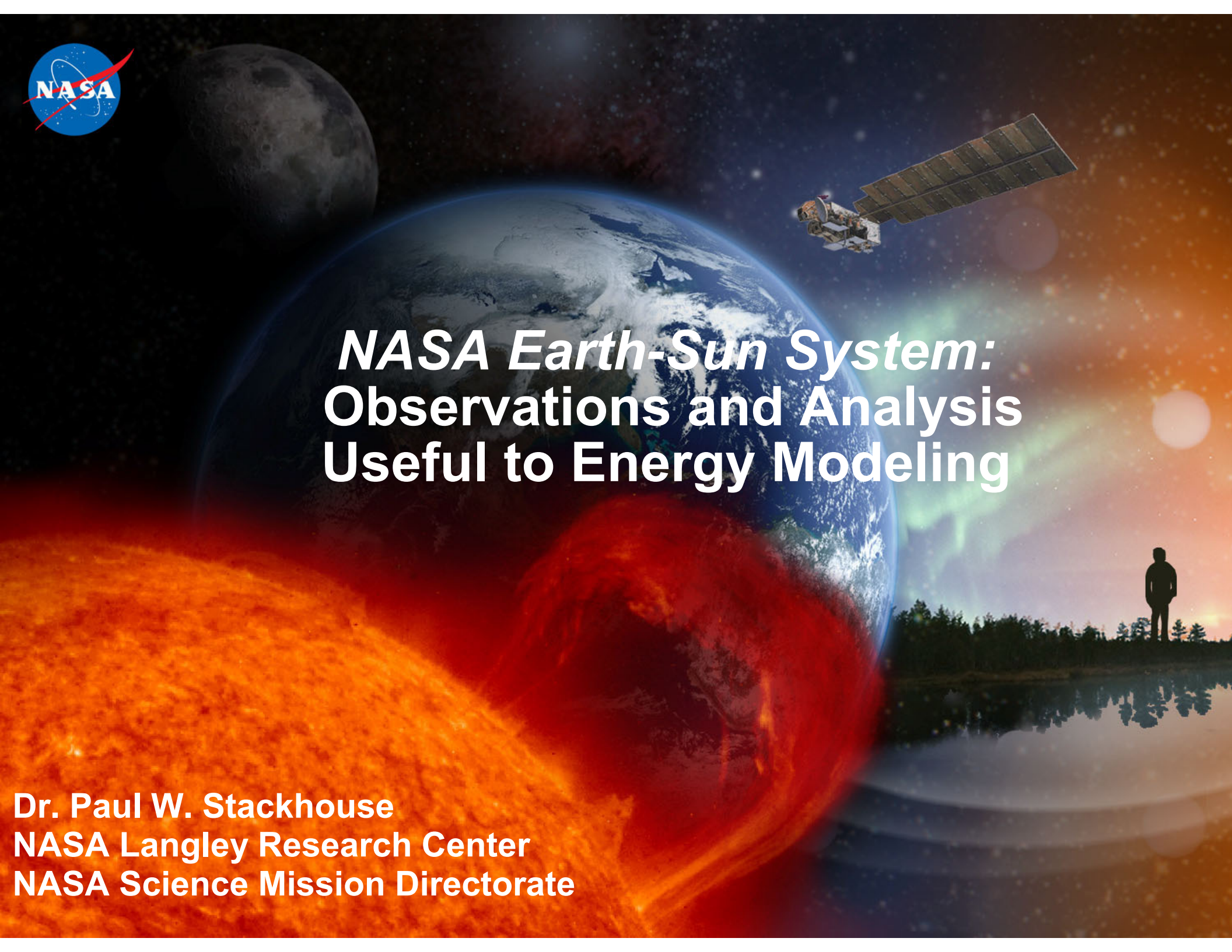
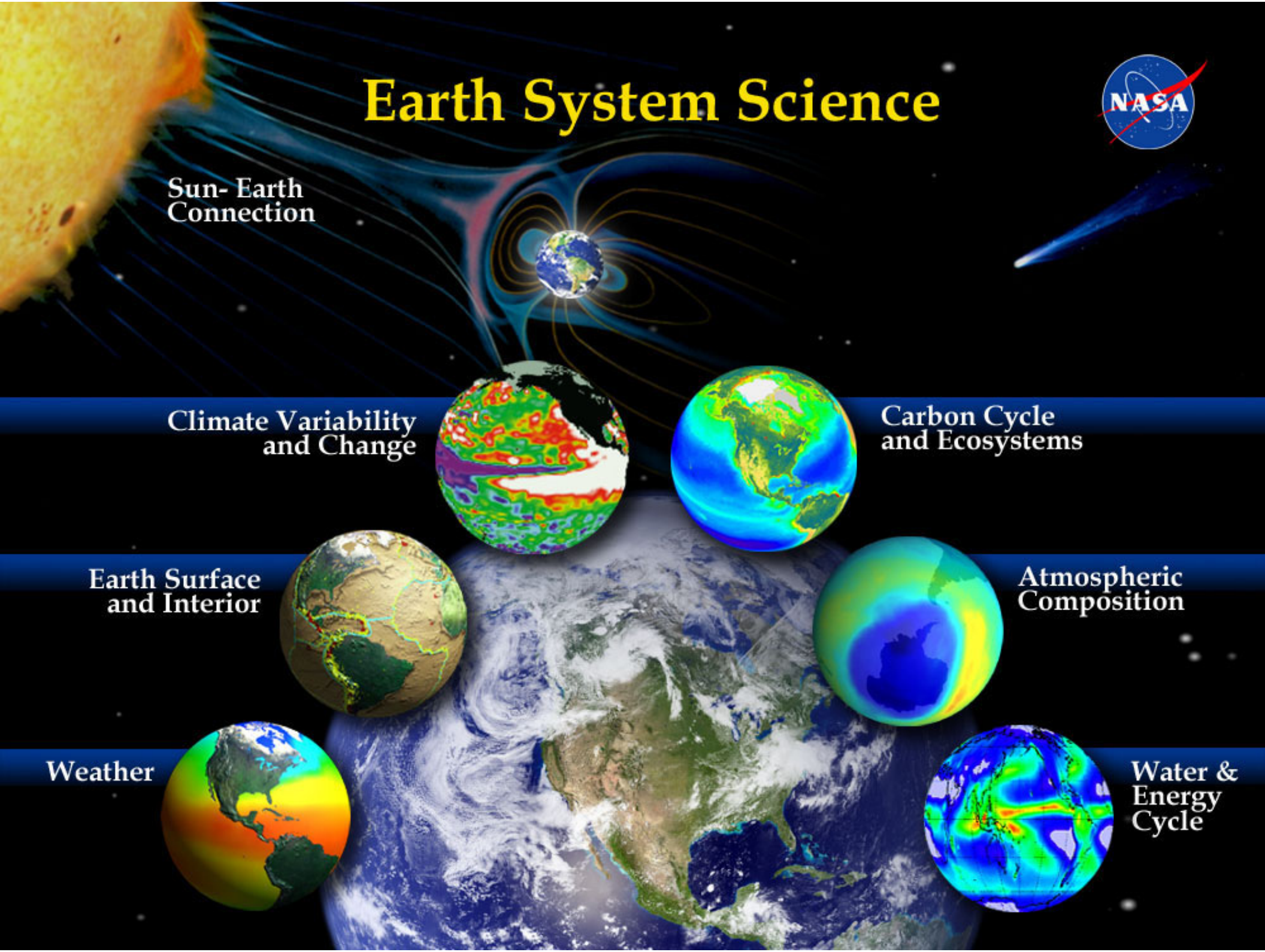
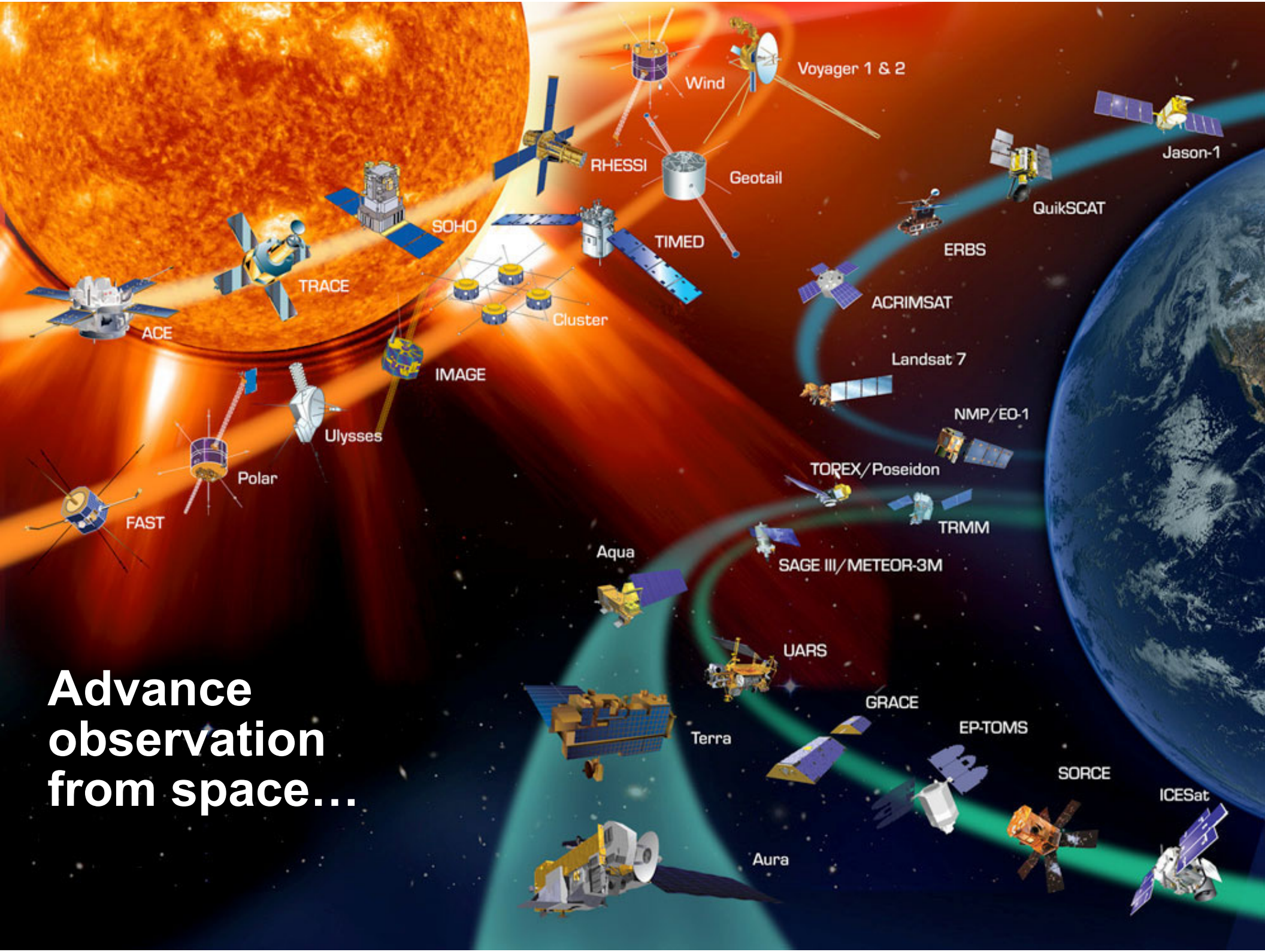


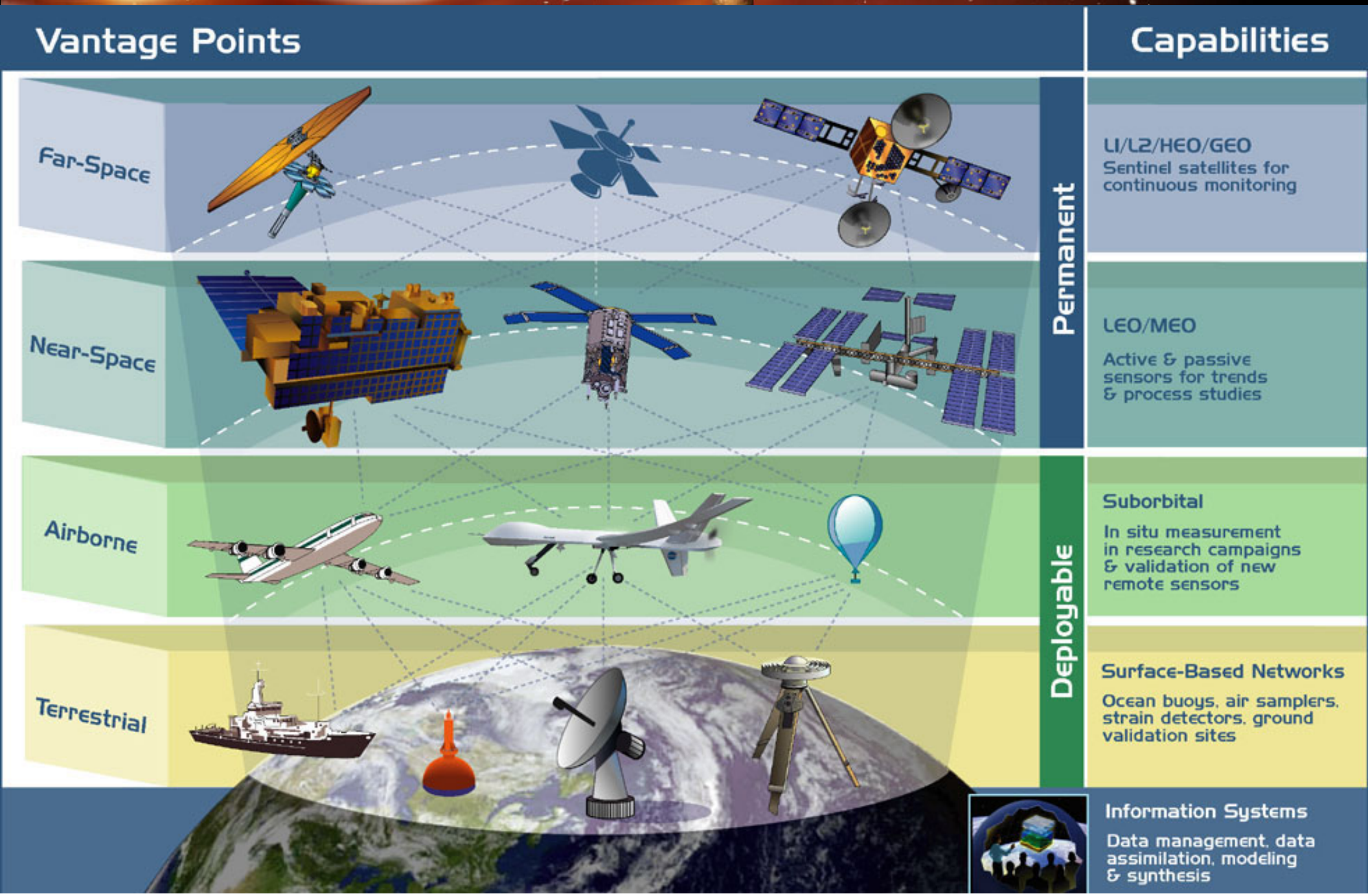
NASA Earth-Sun System: Observations and Analysis Useful to Energy Modeling

Dr. Paul W. Stackhouse
NASA Langley Research Center
NASA Science Mission Directorate

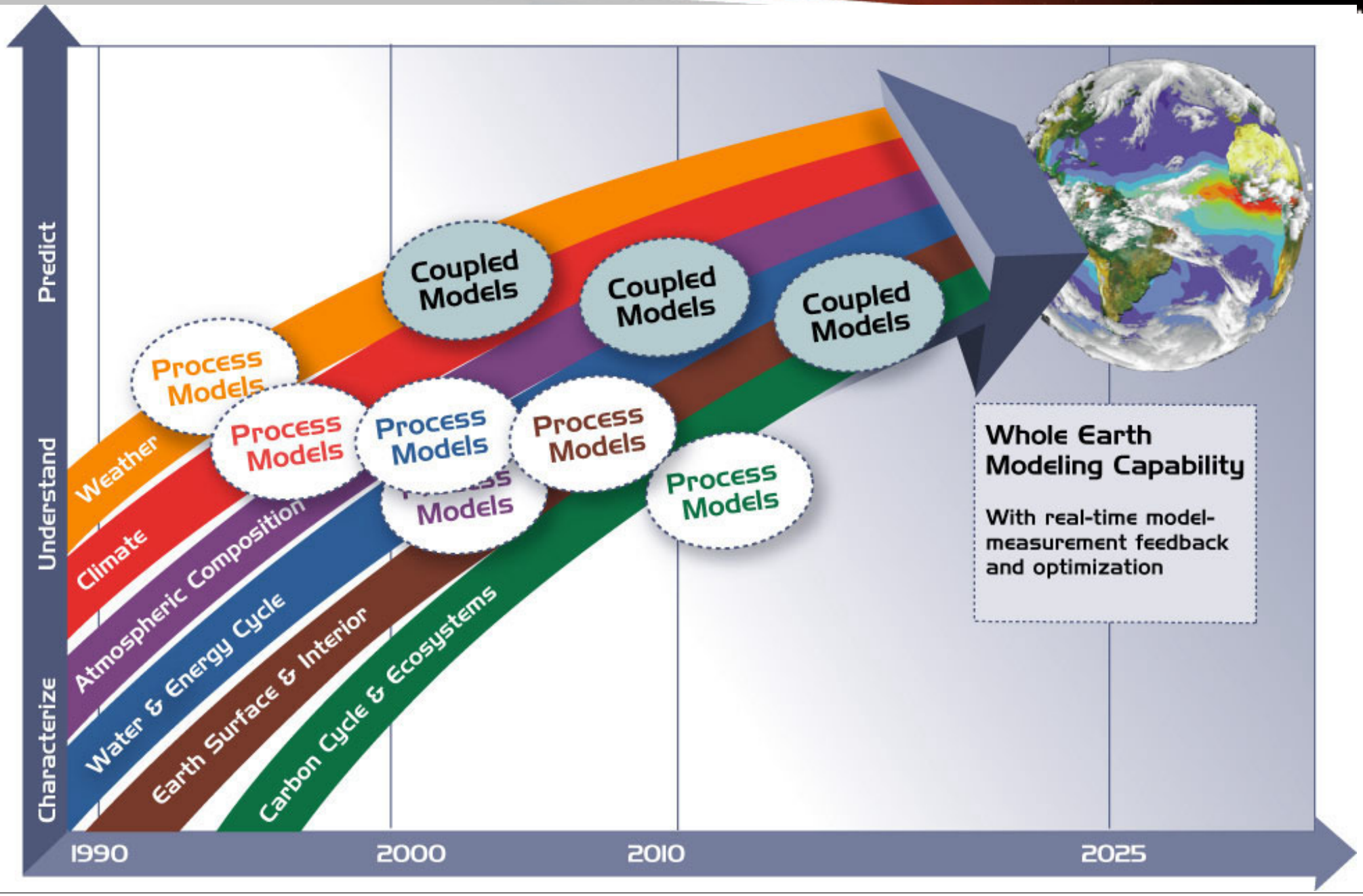

Earth System Science
NASA
Sun- Earth Connection
Climate Variability and Change
Carbon Cycle and Ecosystems
Earth Surface and Interior
Atmospheric Composition
Weather
Water & Energy Cycle


Wind
Voyager 1 & 2
RHESSI
Geotail
Jason-1
QuikSCAT
SOHO
TIMED
ERBS
TRACE
ACRIMSAT
ACE
Cluster
Landsat 7
IMAGE
NMP/EO-1
Ulysses
TOREX/Poseidon
Polar
TRMM
FAST
SAGE III/METEOR-3M
Aqua
UARS
GRACE
Terra
EP-TOMS
SORCE
ICESat
Aura
Advance observation from space…

Global Land Observing System



Focus Area Integration via Earth System Modeling



NASA Example Global Data Sets

Data Source	Example Missions, Projects Data Providers	Geophysical Parameters	Spatial Resolution Range	Temporal Resolution Range
Remote Sensing (algorithms applied directly to radiance at pixel resolution)	LandSat, ASTER, MODIS, MISR, QuikScat, GRACE, TOPEX, TRMM, CERES	Surface type, veg. type, NDVI, Soil Moisture, albedos, skin temp., clouds, aerosols, O3, Geoid Height, Sea Level, TOA solar/IR fluxes	80m – 250m, 1 km, 4 km, 8 km, 50-100 km	1 local time; 2 day - 2 weeks
Higher Level Averaged Products (Multi-pixel)	MODIS, MISR, CERES, MOPITT, TES, TOMS, AMSR-E, WindScat	Clouds, aerosols, TOA fluxes, ocean wind speed, O3, CO2, precipitation, H2O profiles, temp., surface properties, solar fluxes (TOA and surface)	5 km, 10km, 25 km, 0.5°x0.5°, 1°x1°, 5°x5°	3-hourly, daily, 5-day, 16-day, monthly
Higher Level Multi-Instrument Data Products (includes some model inputs)	CERES SARB, ISCCP, SRB, NASA/NOAA GPCP, NVAP, POWER	Clouds, aerosols, atmos +surface fluxes, precipitation, H2O, O3, CO2 (other species), solar and IR fluxes	20 km, 30 km, 1°x1° degree, 2.5°x2.5°	Hourly, daily, 5-day, monthly
Assimilated Data Products	GMAO GEOS, LDAS, RAQMS, GOCART	Temp., H2O, winds, precipitation, energy fluxes, aerosols, O3	10 km, 20-30 km, 1°x1.25° degree	Hourly – 2-day
Model Only (limited operational models)	GMAO FvDAS (NSIPP), GISS Climate Model, SPORT, GOCART, LES	Temp., H2O, winds, precipitation, energy fluxes, aerosols, O3	1-10 km, 25-50 Km, 1°x1.25° 2.5°x2.5° degree	3 hourly, 2-day, monthly, seasonal, climate scenario

National and International Programs benefiting from NASA R&D

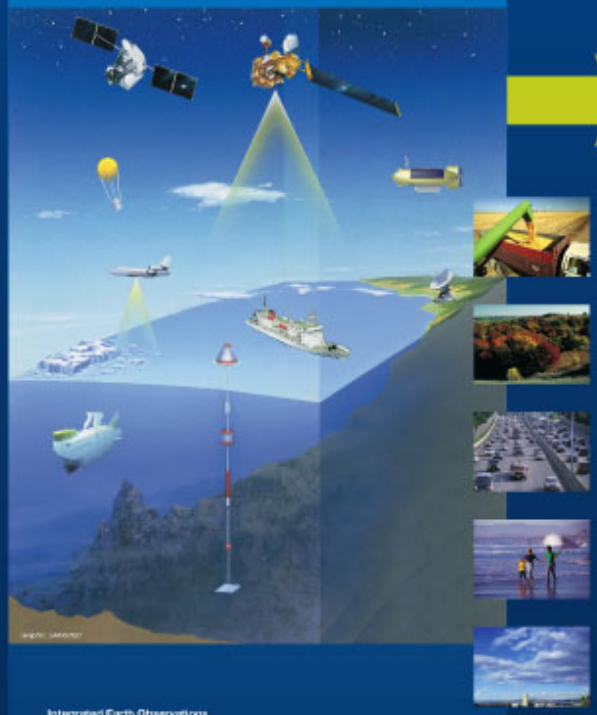
Priority	National Programs	International Programs
Global Earth Observation	Interagency Working Group on Earth Observations (IWGEO) Integrated Earth Observation System, 17 Agencies	Group on Earth Observations (GEO) 55 countries, 33 international organizations
Climate Change	Climate Change Science Program (CCSP, 13 Agencies) Climate Change Technology Program (CCTP, 12 Agencies)	Intergovernmental Panel on Climate Change (IPCC)
Weather	U.S. Weather Research Program (USWRP, 7 Agencies)	World Meteorological Organization (WMO) & THORPEX
Natural Hazards	Subcommittee on Natural Disaster Reduction (SDR, 14 Agencies)	International Strategy for Disaster Reduction (ISDR)
Sustainability	CENR Subcommittee on Ecosystems	World Summit on Sustainable Development (WSSD)
e-Government & Information Services	Geospatial One-Stop (GOS, 12 Agencies) and the Federal Geographic Data Committee (FGDC, 19 Agencies)	World Summit on the Information Society
Commercial Remote Sensing	U.S. Commercial Remote Sensing Space Policy	

CTTP: Solutions for Energy Policy Decisions

Measurements and Monitoring Framework for the Climate Change Technology Program Strategy

supply → demand

MEASUREMENTS AND MONITORING TECHNOLOGIES



Integrated Earth Observations

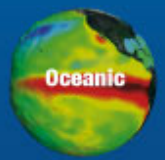
United States agencies observe the Earth across a hierarchy of spatial scales, on their own as well as in partnership with other agencies, commercial endeavors, and international entities. Earth observation technologies enable measuring and evaluating systems that observe and account for the quantities and fluxes of greenhouse gases in the Earth's atmosphere, including CO_2, CH_4, NO_2, HFCs, PFCs, SF_6, O_3, ozone precursors, and aerosols and black carbon. Of equal importance, these technologies enable systems that observe and account for the sequestration of CO_2, including approaches for long-term holding of atmospheric carbon in oceanic, terrestrial and geologic reservoirs. The global and long-term nature of the challenge requires observations across spatial scales from local to global, and across temporal scales from instantaneous monitoring of point sources and sinks to decadal monitoring of atmospheric composition and carbon accumulation.

The Climate Change Technology Program (CCTP) will enable a hierarchical system of measuring and monitoring tools, including sensors deployed on satellites and aircraft, observations from ground networks, point source sensors, and in situ stations.

ASSESSMENT AND MODELING

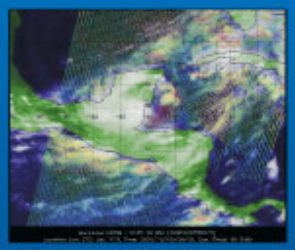
CO_2 CH_4 NO_2 Black Carbon SF_6 O_3

EMISSION: measure and monitor emission sources and sinks or proxies of emissions



SEQUESTRATION: measure and monitor

SCENARIO ASSESSMENT TOOLS



ENERGY/CLIMATE: MINI-Climate Assessment Model

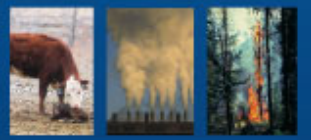
ENERGY/CLIMATE: Process Global Climate Assessment Model

AIR QUALITY: Community Multiscale Air Quality Modeling System

EMISSION REDUCTION OR STABILIZATION TECHNOLOGIES

Production

Efficiency



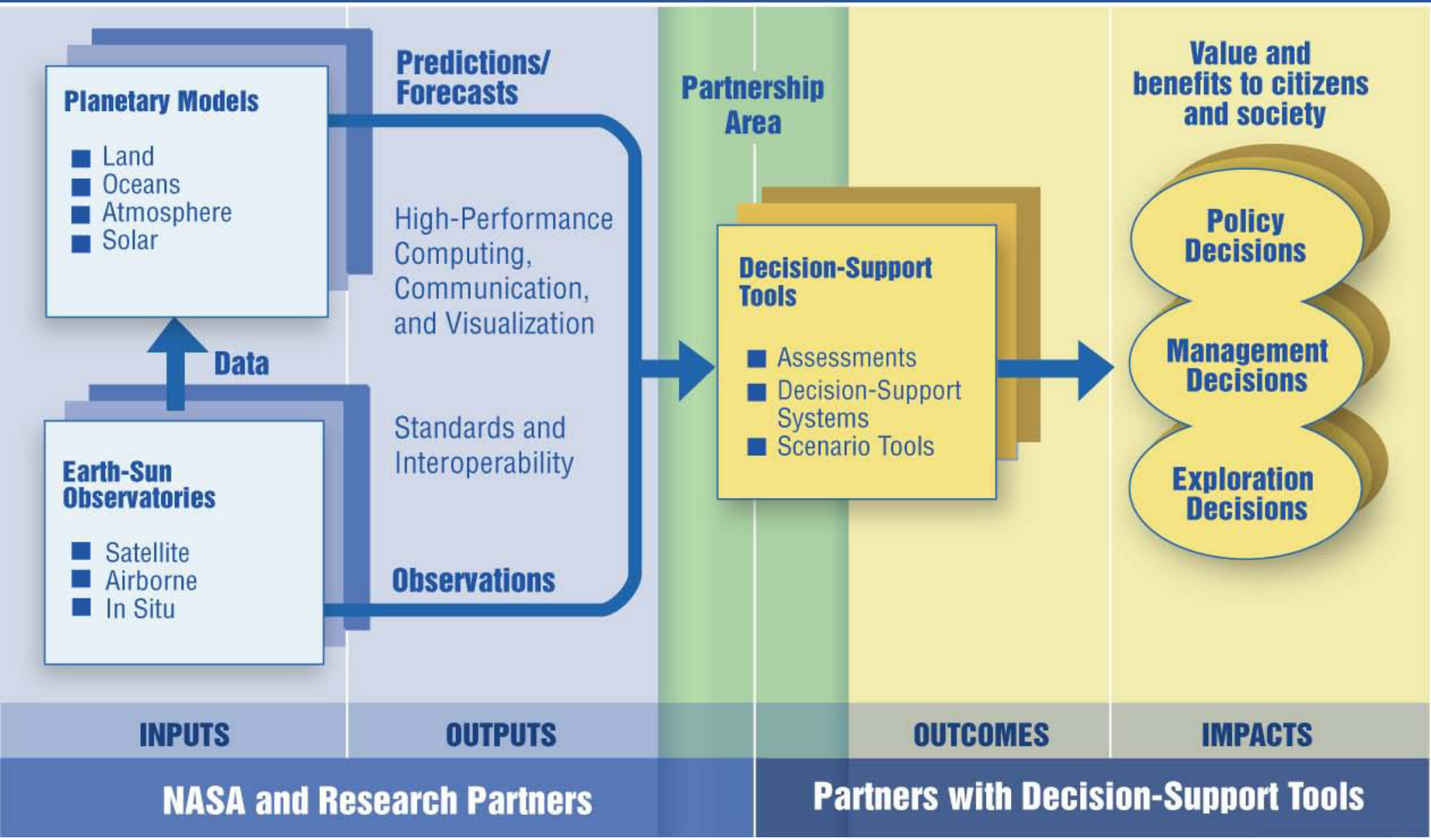
other sources of greenhouse gases

Air Quality

carbon sequestration

Sequestration

Earth-Sun System Applied Science Systems Approach



Applications of National Priority

Agricultural Efficiency

Air Quality

Aviation

Carbon Management

Coastal Management

Disaster Management

Ecological Forecasting

Energy Management

Homeland Security

Invasive Species

Public Health

Water Management

National Application	Partner Organizations	Decision-Support Systems
Agricultural Efficiency	USDA,NOAA	CADRE—Crop Assessment Data Retrieval and Evaluation (USDA)
Air Quality	EPA,NOAA,USDA	CMAQ—Community Multiscale Air Quality Modeling System AIRNow AQI—Air Quality Index
Aviation	DOT/FAA,NOAA	NAS-AWRP—National Air Space-Aviation Weather Research Program
Carbon Management	USDA,DOE,NOAA	CQUEST—Support to the Energy Act of 1992,Section 1605b
Coastal Management	NOAA,EPA,NRL	HAB—Harmful Algal Bloom Bulletin/Mapping System CREWS—Coral Reef Early Warning System
Disaster Management	DHS/FEMA,NOAA,USGS,USFS	AWIPS—Advanced Weather Interactive Processing System HAZUS-MH—Hazards U.S.—Multi-Hazards
Ecological Forecasting	USAID,NOAA,NPS,CCAD,USGS	SERVIR—Regional Visualization and Monitoring System
Energy Management	DOE,UNEP,NOAA,NRC	**RETScreen – Renewable Energy Planning (Natural Resources Canada)** **HOMER – Renewable Energy System Optimization**
Homeland Security	DHS,USGS,NOAA,NGA,DOD	IOF—Integrated Operations Facility IMAAC—Interagency Modeling and Atmospheric Assessment Center
Invasive Species	USGS,USDA,NOAA	ISFS—Invasive Species Forecasting System
Public Health	NIH,CDC,DOD,EPA	PSS—Plague Surveillance System EPHTN—Environmental Public Health Tracking Network MMS—Malaria Monitoring and Surveillance RSVP—Rapid Syndrome Validation Project
Water Management	EPA,USDA,USGS,BoR	RiverWARE—Bureau of Reclamation decision-support Tool AWARDS—Agricultural Water Resources and decision-support Tool BASINS—Better Assessment Science Integrating Point and Nonpoint Source

NASA Energy Management

Prediction Of Worldwide Energy Resource Project

NASA POWER Project

Objective: ***Improve the Nation's public and private capability for integrating environmental data into sound management of energy production and energy efficiency systems.***

Goals:

1. ***Establish partnerships to facilitate the integration and adaptation of NASA satellite analysis and modeling data into electric power industry Decision Support System's (DSS) and databases.***
2. ***Target such datasets for Electric Power, Renewable Energy, Energy-Efficient Building Design and Biomass Crop Development Industries***
3. ***Transition operational capabilities to government and/or private sector entities.***

NASA POWER Project:

Integrated System Solution

EARTH SYSTEM MODELS

- Earth System & Climate Change: ***GMAO Analysis, NCEP Analysis***
- Seasonal Prediction Models: ***NSIPP Analysis, NCEP Analysis***
- Aerosol Transport Models: ***RAQMS, GMAO fvCAM, NCAR WRF, GFDL FMS Atmosphere***
- Climate Models: ***GISS Model II, GFDL FMS B-Grid Atmosphere***
- Atmospheric Analysis Projects: ***ISCCP, SRB, CERES-SARB, GVAP, GPCP***

***Supported Non-NASA Model**

Predictions

- 20+ years
- Past 90 days
- 1 – 15 day forecasts
- 12 – 18 month seasonal forecasts
- 10 – 20 year forecasts

Data

- Temperature & humidity profiles
- Cloud systems
- Land cover albedo
- Land surface temperature
- Soil Moisture
- Ocean Surface Winds
- Global Precipitation
- Total Aerosol Amount
- Land Surface Topography
- Trace gas profiles

Observations

EARTH OBSERVATIONS

- **Atmosphere:** *GOES, POES, TRMM, Terra, Aqua, TOMS, Aeronet, AIRNow,* ***INTEX, Aura, CALIPSO, APS, CloudSat, GPM, NPP, GIFTS, HYDROS***
- **Land :** *Terra, Aqua, Landsat, Terrestrial Networks, BSRN, ARM, SURFRAD,*

***Future Mission**

DECISION SUPPORT TOOLS

NREL

- HOMER
- National Solar Radiation Database (NSRDB)
- Provides data sets for numerous energy management decisions

EPRI

- Neural Net Load Forecast Tools
- Forecasting tool for Energy industry
- Integration of renewable sources to traditional power grids

RETScreen

- Provides common platform for evaluating project proposals while significantly reducing the costs and uncertainties of preliminary studies
- Reduces the time and errors of a preliminary study

energy.gov U.S. DEPARTMENT OF ENERGY

UNEP

Natural Resources Canada

NOAA

VALUE & BENEFITS

- Optimize renewable energy systems for power production
- Optimal integration of traditional and renewable energy supply systems into electric power grid
- Improved prediction of electric power need and supply – mitigate power shortages, prevent price increase
- Reduction in greenhouse emissions from energy production

NASA POWER Project:
Logistical Approach

NASA Input Sources

Satellite-Based Retrievals and Analysis
(ISCCP, SRB, CERES)

Data Assimil-ation
(GMAO, NOAA NCEP)

Forecast Models From 1-day to Climate time scales:
(NASA GMAO, NSIPP, GISS; NOAA Wx, SFM, GFDL)

POWER
Integration and Algorithm Benchmarking

DSS Needs

Historic Records:
Renewables (RETScreen, NREL), Buildings (ASHRAE), Biomass, Utilities (EPRI)

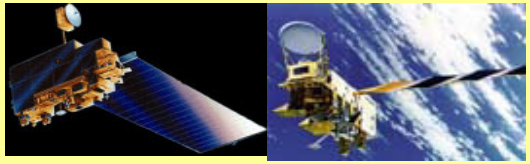
Near-Term Records (last 90 days):
Utilities (EPRI), Biomass

Forecasts (day – yrs):
Utilities (EPRI), Renewables (NREL), Buildings (ASHRAE), Biomass

POWER Historical data for Renewable Energy

Earth-Sun System Science → Applied Science Outcome

NASA Satellite Measurements, Analysis and Modeling

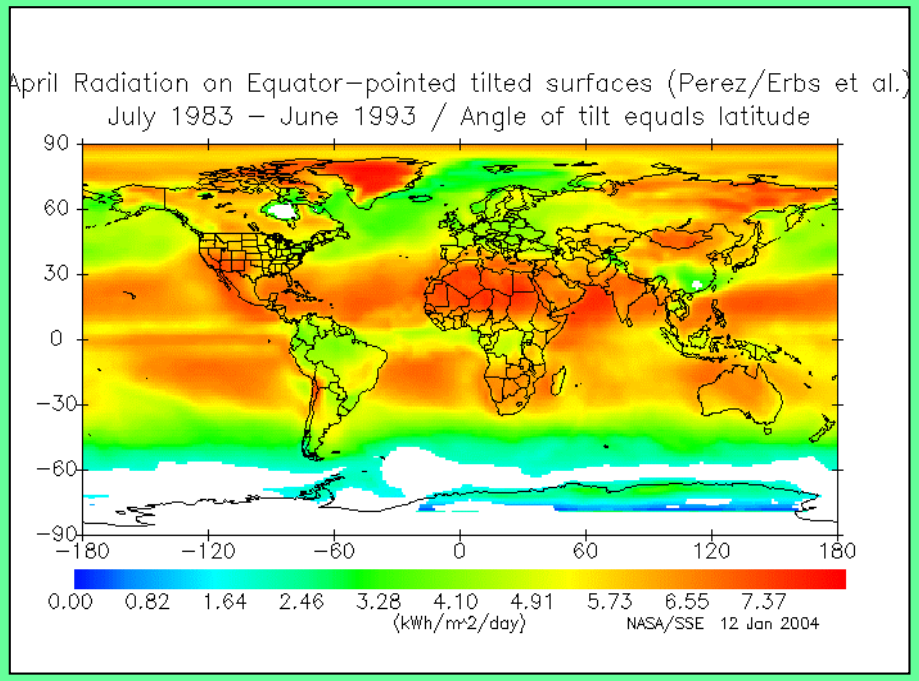


Terra Aqua

ISCCP SRB GMAO CERES

Surface Meteorology and Solar Energy (SSE) Datasets And Web interface

SSE



SSE Web Site

http://eosweb.larc.nasa.gov/sse/

Over 200 solar energy and meteorology parameters averaged from 10 years of data

Growing over the last 4 years to nearly 14,000 users, 2.5 million hits and 520,000 data downloads

POWER Partnership Example:

RETScreen from CEDRL

Natural Resources Canada
RETScreen

RETScreen Design System
(~40,000 Global Users)

Photo Credit: Green Mountain Power Corporation/ NRELPix

Solar Water Heating

POWER Partnership Example:

RETScreen/SSE Data Retrieval Example

Natural Resources Canada RETScreen

Project Costs and Savings

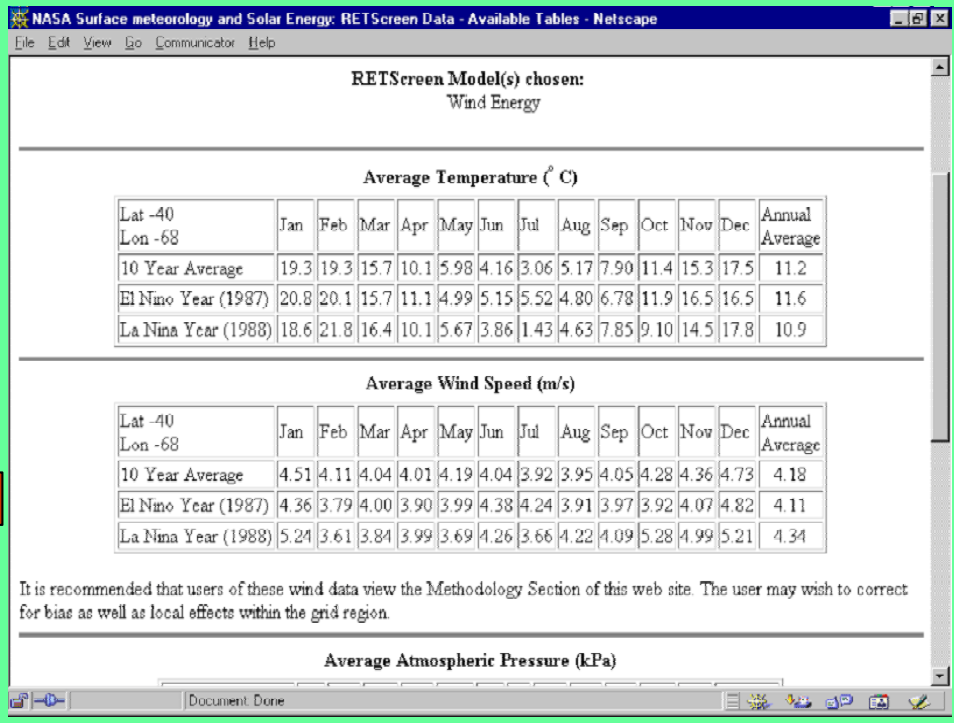
Initial Costs				Annual Costs and Debt		
Feasibility study	0.6%	$	195,200	O&M	$	913,332
Development	2.5%	$	770,500			
Engineering	2.0%	$	610,500	Debt payments - 20 yrs	$	2,298,426
RE equipment	68.4%	$	21,260,000	**Annual Costs - Total**	**$**	**3,211,757**
Balance of plant	18.9%	$	5,868,000			
Miscellaneous	7.6%	$	2,368,336	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**31,072,536**	Energy savings/income	$	3,127,880
				Capacity savings/income	$	-
Incentives/Grants		$	-	RE production credit income - 10 yrs	$	1,689,055
				Annual Savings - Total	**$**	**4,816,935**
Periodic Costs (Credits)						
Drive train		$	1,000,000	Schedule yr # 10,20		
Blades		$	1,000,000	Schedule yr # 15		
		$	-			
End of project life - Credit		$	-			

Financial Feasibility

				Calculate RE production cost?	yes/no	No
Pre-tax IRR and ROI		%	20.6%			
After-tax IRR and ROI		%	20.6%			
Simple Payback		yr	8.0	Project equity	$	9,321,761
Year-to-positive cash flow		yr	4.8	Project debt	$	21,750,775

RETScreen Design System (~40,000 Global Users)

Surface Meteorology and Solar Energy (SSE) Datasets And Web interface



Last 4.5 years: nearly 14,000 users, 2.5 million hits and 520,000 Data Documents

POWER SSE Datasets:
Data Access and Availability

Public:
1. Register
2. On-line Request
3. Data received

On-the-fly SSE Web Site and Data Archive
> 200 Monthly Parameters (64,800 cells):
132 in Stored Files, **70+** calculated
> **1,000,000** Monthly Maps generated on user request

Partner Page on SSE Web Site:
RETScreen, SolarSizer, NREL HOMER

Partners provide technical advice and/or validation data to NASA: NREL, CEDRL

Partner Requested Data from NASA:
SWERA (NREL), RETScreen (CEDRL), NSRDB (NREL)

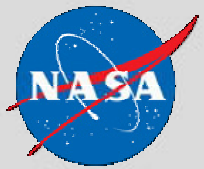
User Software:
RETScreen, HOMER (testing), Solar Sizer

User Requested Datasets:
- RETScreen (through UNEP)
- SWERA (to UNEP GRID)
- NSRDB (to NREL – future delivery)

POWER Vision

Additional Web-based Data and Prototypes

- **Historic global datasets and industry prototypes:**
  - SSE Rel. 5 (spanning July '83 – Oct '95): imminent
  - SSE Rel. 5.5 (spanning Nov. '95 – Sep. '01): Summer 2005
  - 20+ Year SSE: middle 2006
- **Near-term global prototype datasets (FLASHFlux/CERES):**
  - Prototype operational system (archived up to 6 months from real-time): Fall 2006
- **Forecasted datasets:**
  - Preliminary discussions w/ modeling partners underway; new partners being sought in climate prediction
  - Short-term regional prototype - Summer 2005
  - Seasonal prototypes 2005-2006



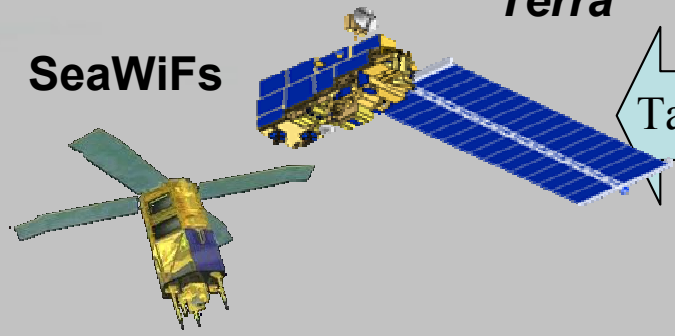
Carbon Management

USDA

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Terra

SeaWiFs

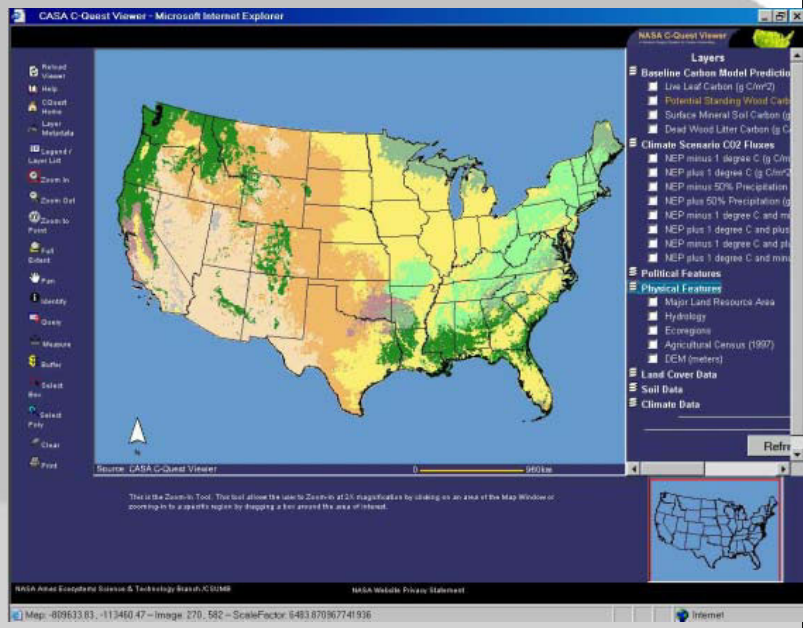


Tasking

EDOS: Mission Control

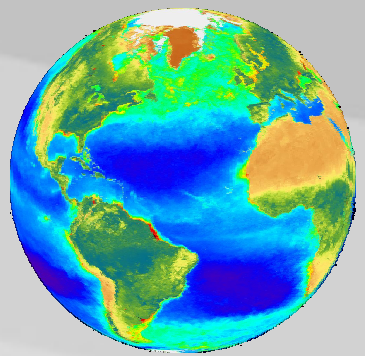
Downlink

Societal Benefits

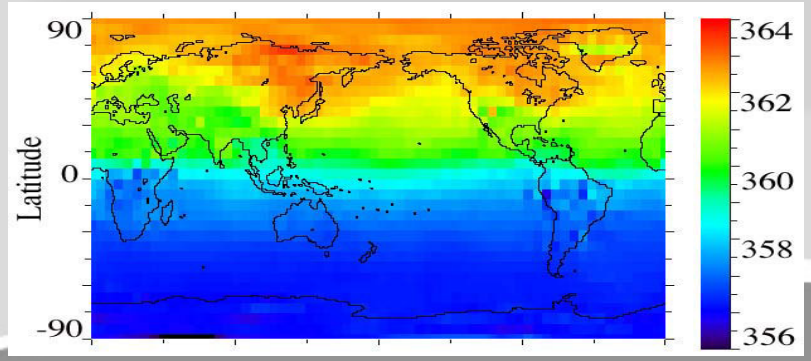


CASA/CQUEST

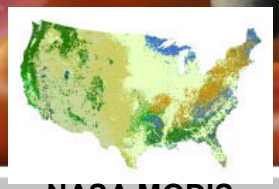
Exploitation



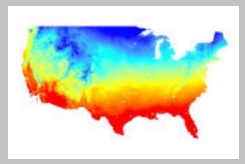
EOSDIS & DAACs



NASA / NGA SRTM Elevation

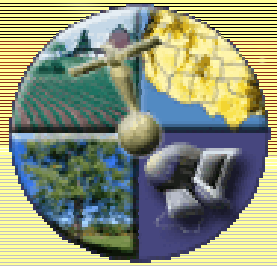


NASA MODIS Products

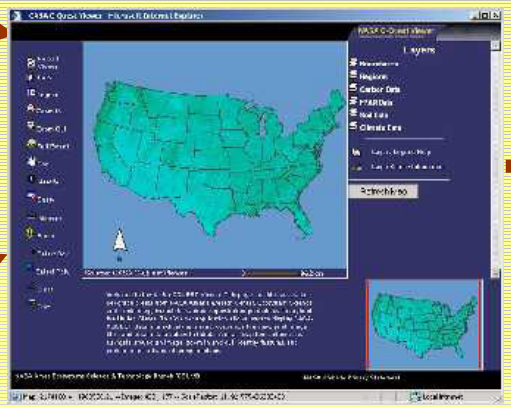


VEMAP & Daymet (UMT) Climate data

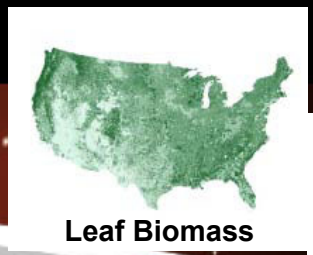
Inputs include continental-scale land cover, NDVI, FPAR, elevation, soils, and climate data …



CASA CQUEST – A Decision Support System for Carbon Accounting



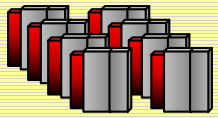
User Defined Profile
Region of Interest
Time Frame
Biophysical
Management
Climate Scenario



Leaf Biomass

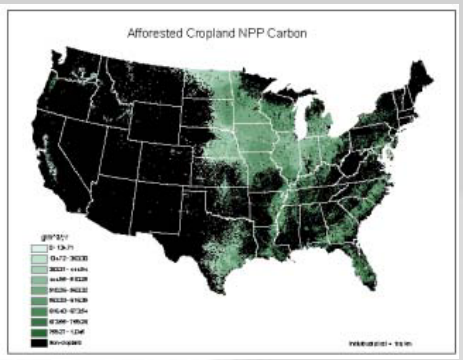
Cropland NPP

Output: landscape-to continental scale predictive maps of above and below ground distributions of sequestered carbon for different climate scenarios

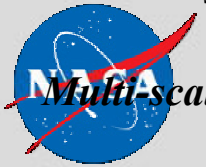


USFS Forest Inventory and Analysis Data

Carbon Sequestration Predication

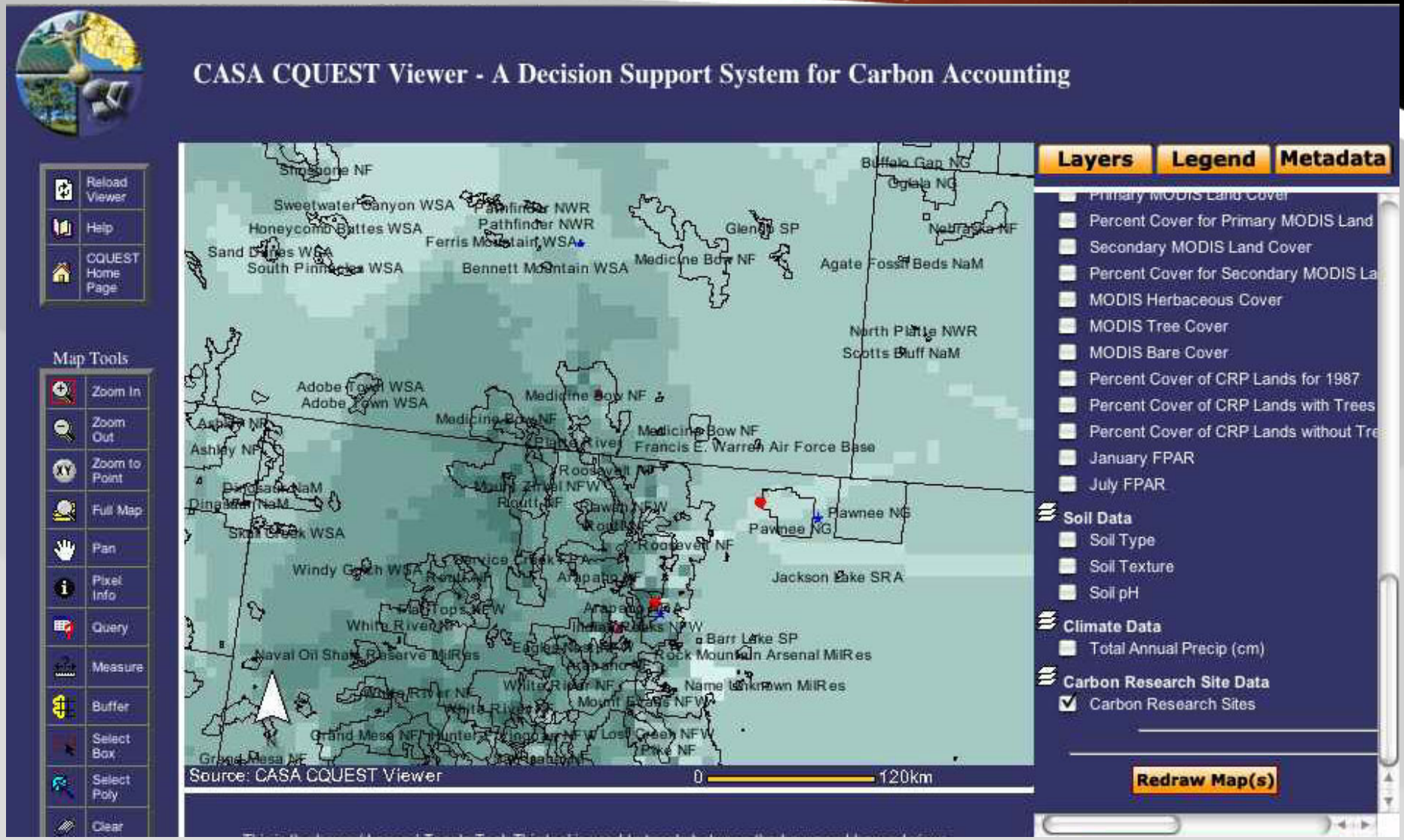


Cropland Afforestation Prediction



Multi-scale Validation Information

CASA Model Predictions at NACP Sampling Protocol Sites

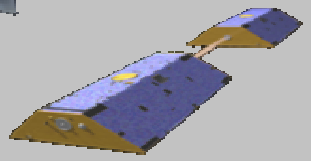


NASA/USDA Carbon Cycle Science project: *Linking Landscape-Scale Carbon Monitoring with Forest Management*; PI: Richard Birdsey, USDA Forest Service

Disaster Management

QuikScat

GRACE



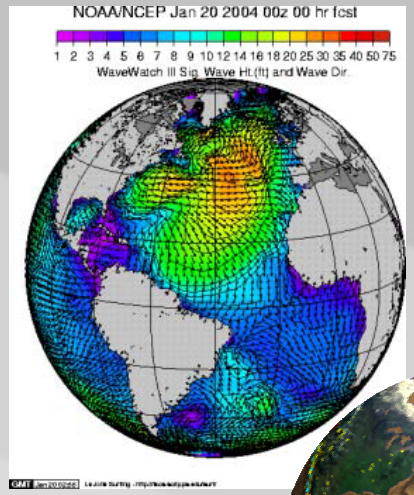
Tasking

EDOS: Mission Control

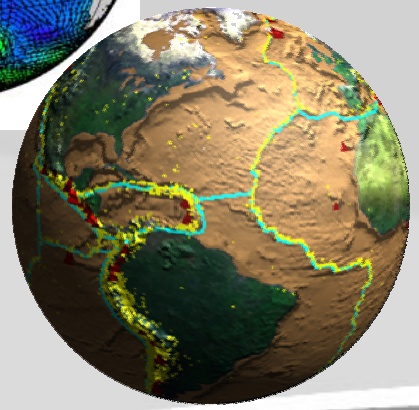
Downlink

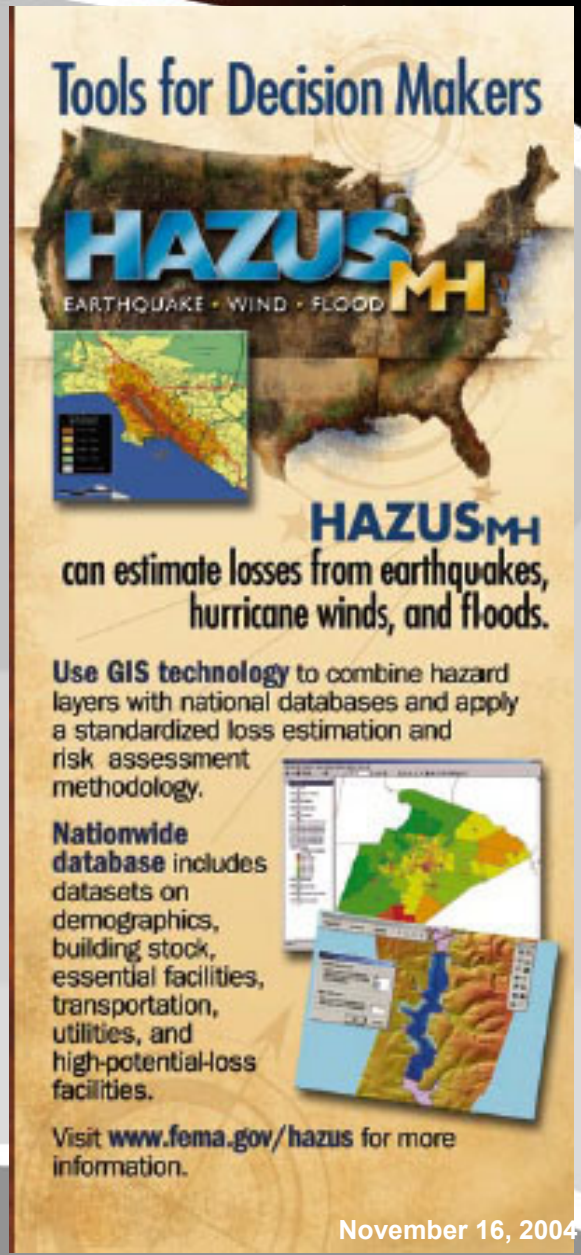
Exploitation

EOSDIS & DAACs



Societal Benefits



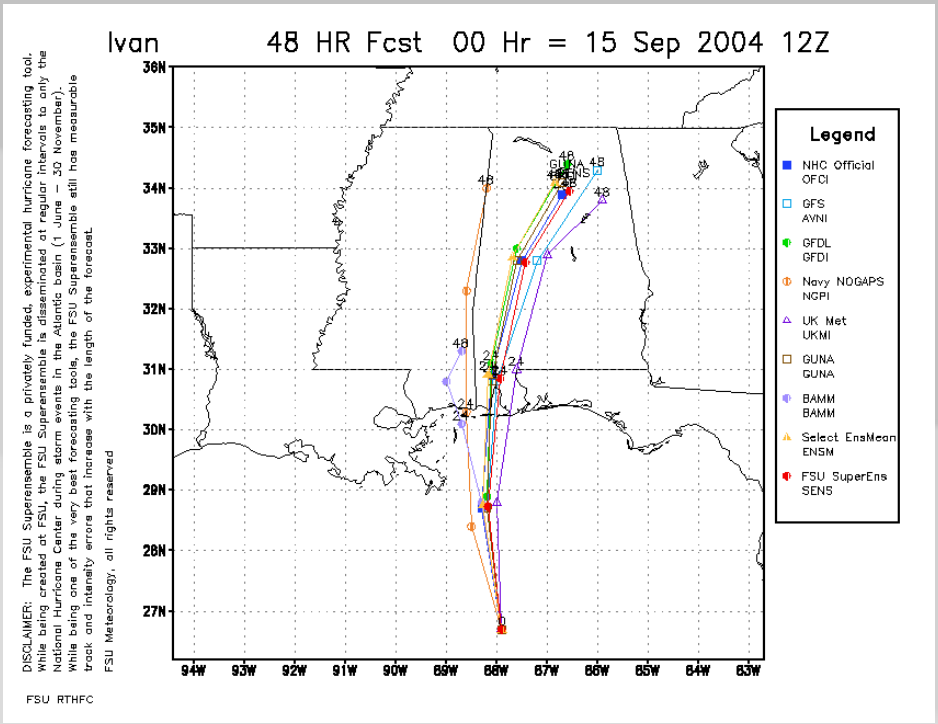


November 16, 2004

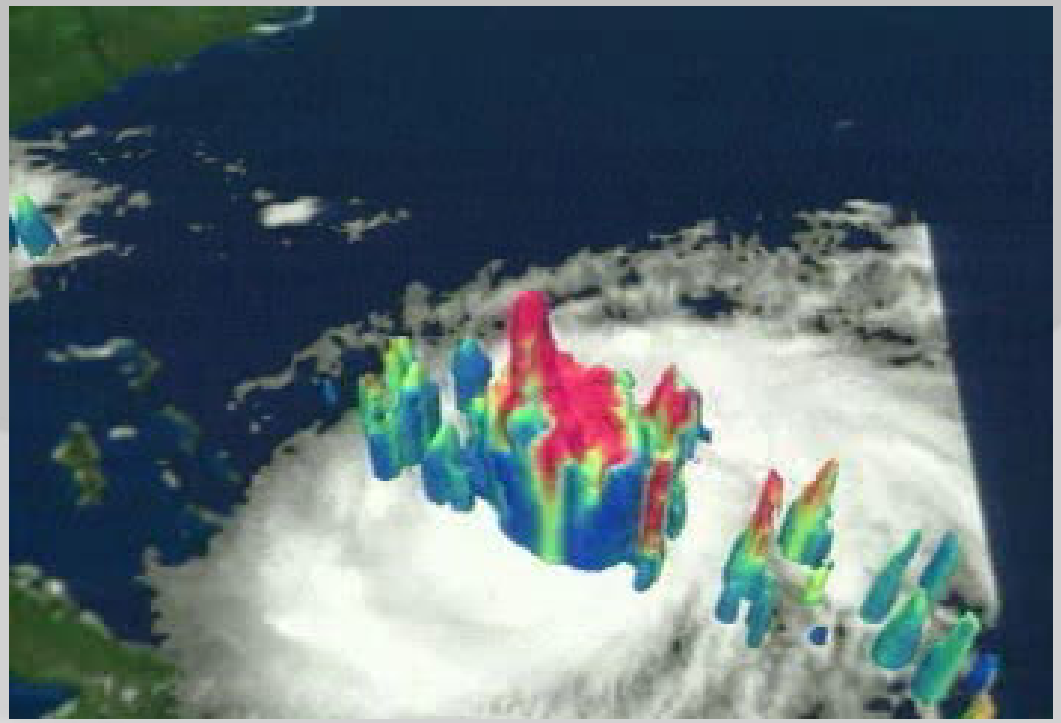
Applying Earth Observations to improve Hurricanes forecasts

Assimilation of TRMM rainfall location, intensity and vertical structure into hurricane forecast models leads to improvements in forecasts of future position

Hurricane Ivan Forecast, September 2005



Hurricane Visualization with TRMM data



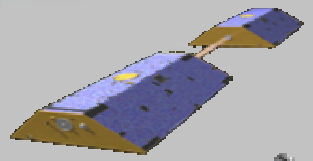
Reduced track errors can save money ($600K - $1M per mile of coast evacuated) and save lives by more precise prediction of eye location at landfall

Water Management

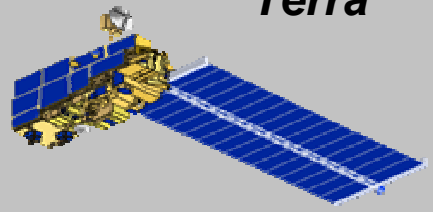
Bureau of Reclamation
Managing Water In The American

USGS
science for a changing world

GRACE



Terra



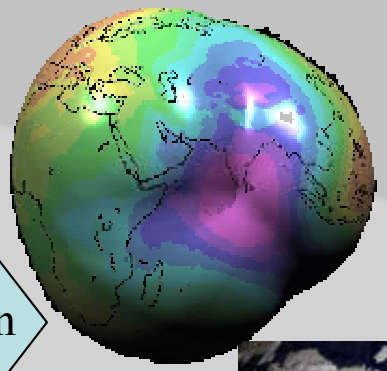
Tasking

EDOS: Mission Control

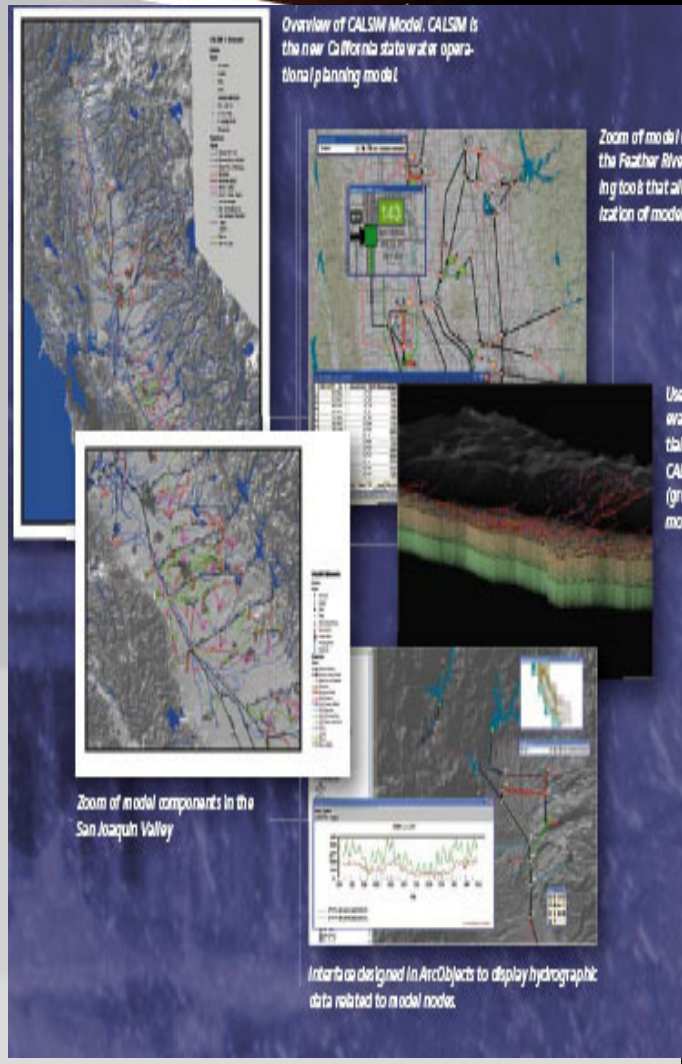
Processing

EOSDIS & DAACs

Exploitation



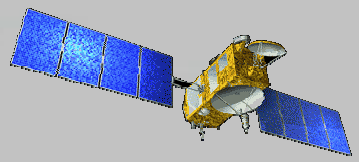
Societal Benefits



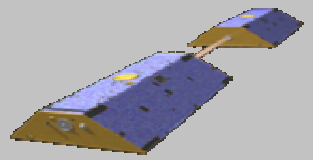
Riverware & AWARDS

Water Management:
Drought Information System

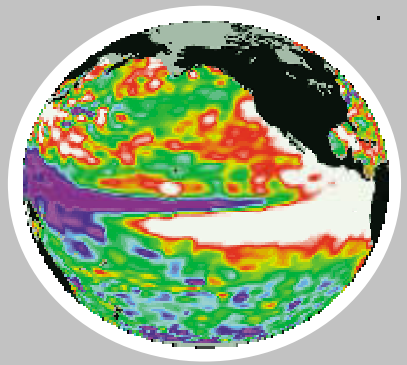
Jason



GRACE



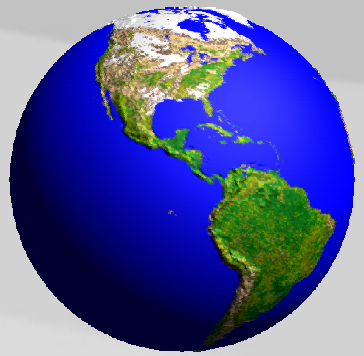
Terra



Downlink

Societal Benefits

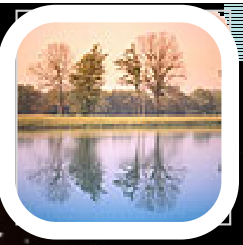
Exploitation



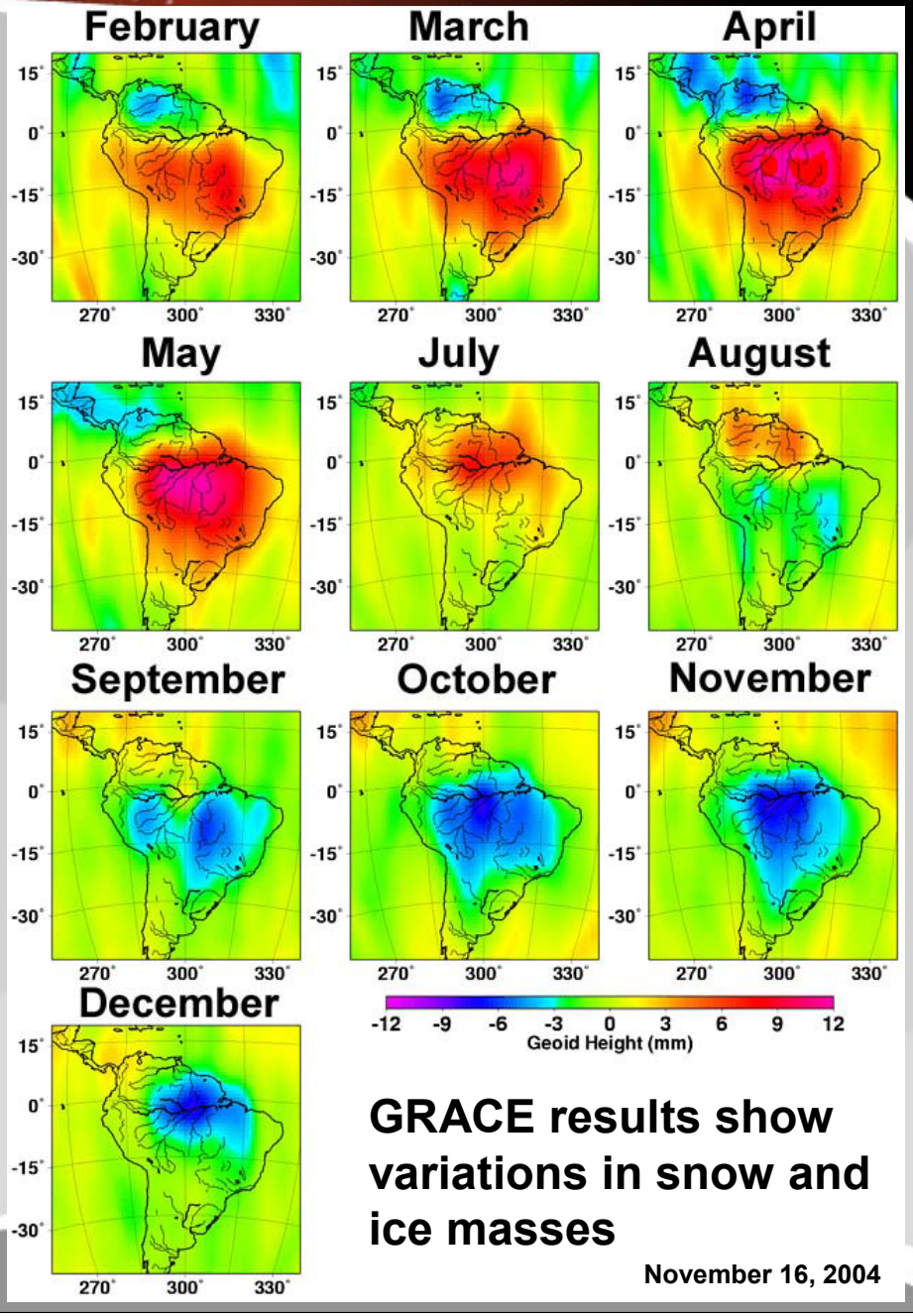
EOSDIS & DAACs

CADRE:
USDA Decision Support System for Global Crop Production Assessments

Evaluating the use of Water Cycle Research Results



Variation in global snow cover for the period from 2001- 2002 derived from NASA observations



GRACE results show variations in snow and ice masses

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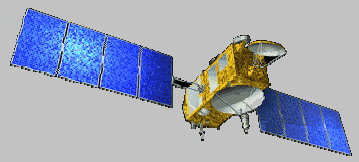
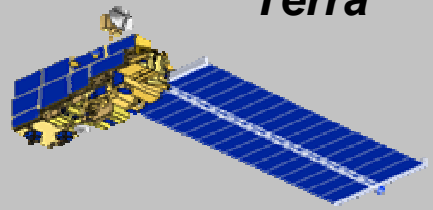
Agriculture Efficiency

Jason



Terra



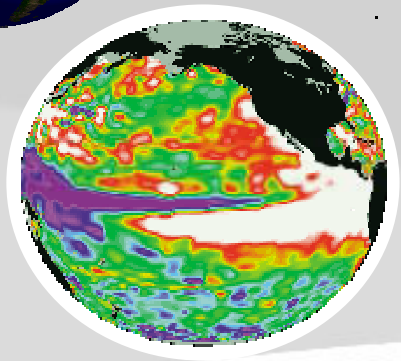
Tasking

EDOS: Mission Control

Downlink

Societal Benefits

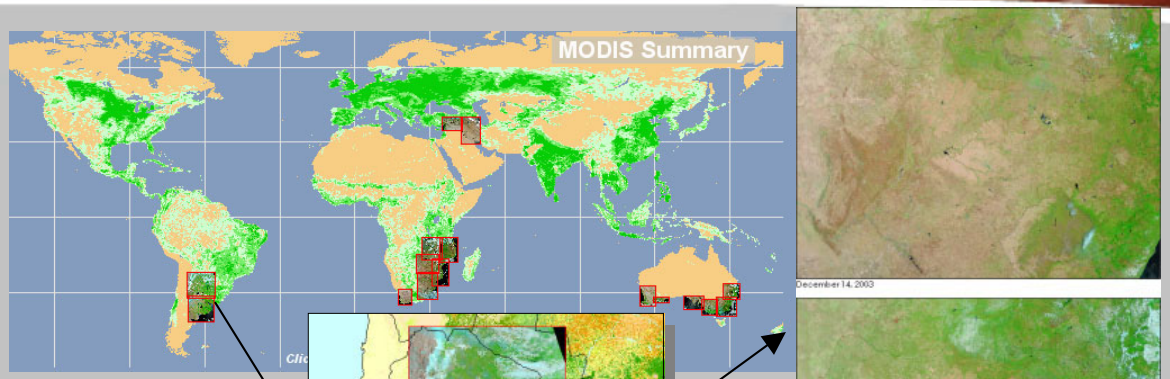
Exploitation



EOSDIS & DAACs

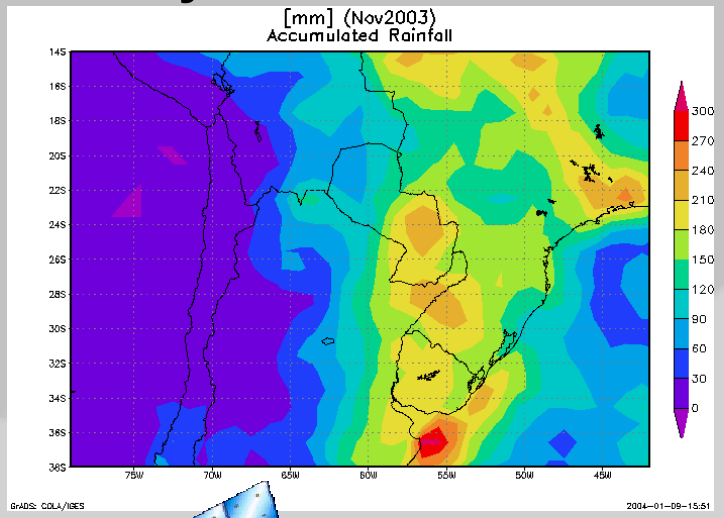
CADRE:
USDA Decision Support System for Global Crop Production Assessments

Applying NASA Research Results for improving Crop Production Assessment

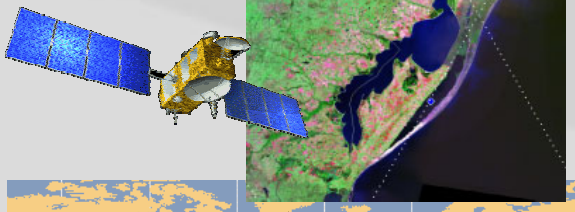


MODIS Rapid Response products provide timely looks at crop condition

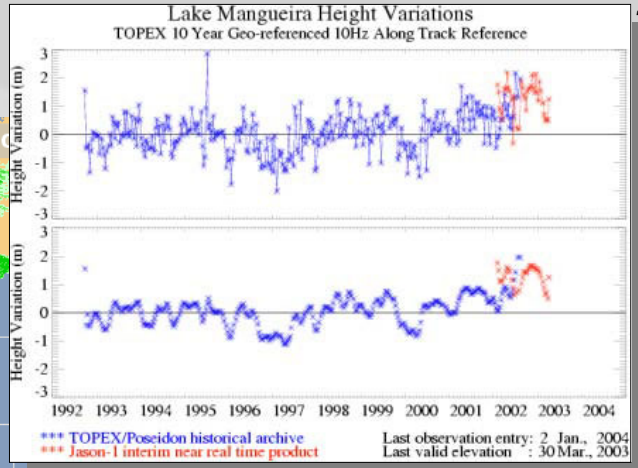
EOS products
Productivity modeling (FAS)
WAOB Estimates
Policy/Resource Decisions

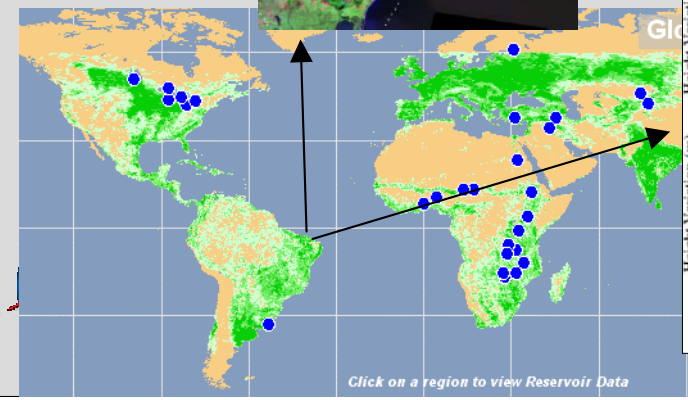


Jason

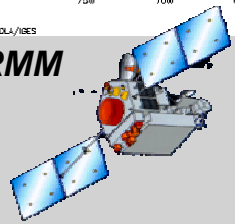


TOPEX and JASON-1 products provide lake level data in critical irrigated areas





TRMM



TRMM products provide better data on available water

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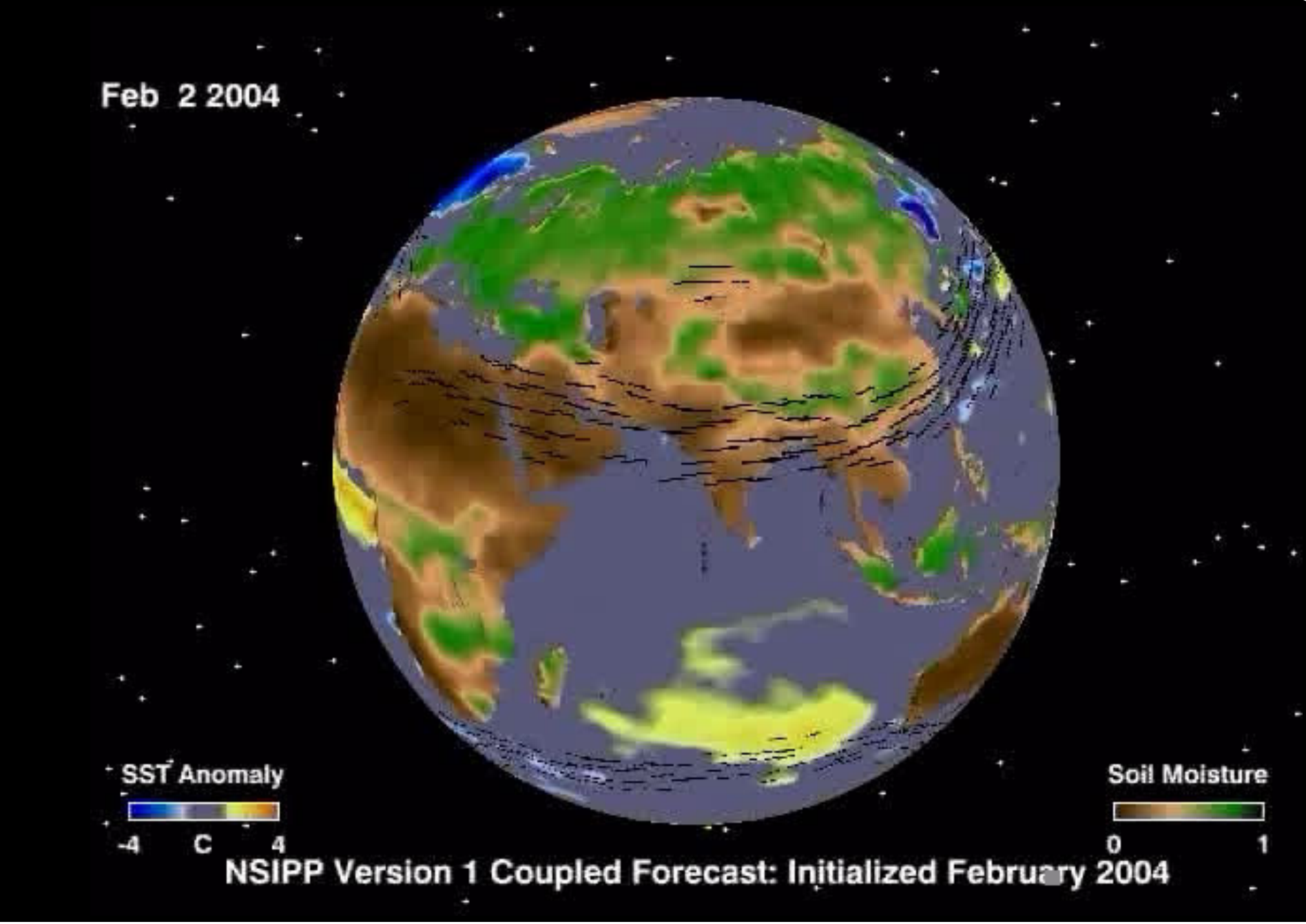
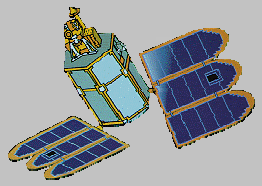
Agricultural Effeciency: 12 Month Coupled Climate Forecasts for Agriculture

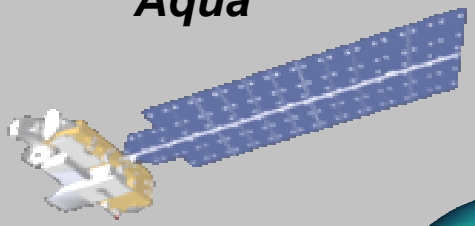


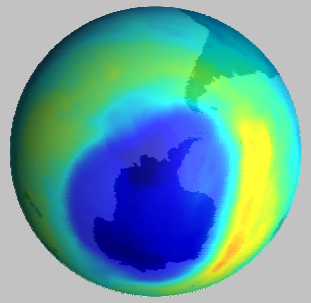
Air Quality Forecast System

TOMS-EP



Aqua

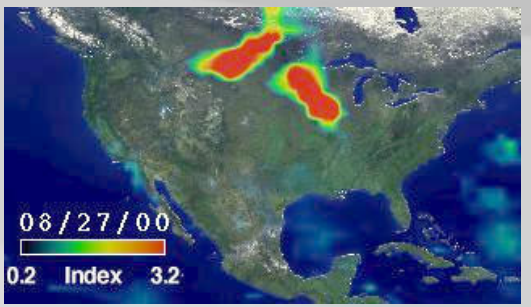




Downlink

Societal Benefits

Exploitation

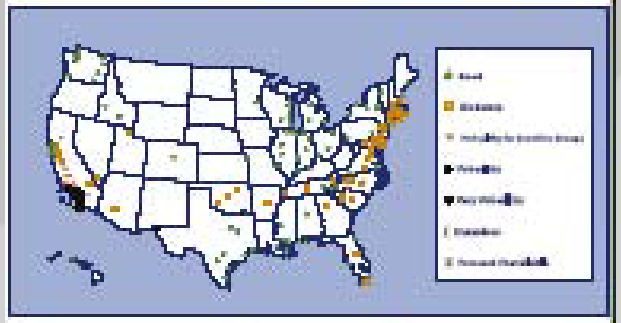


EOSDIS & DAACs

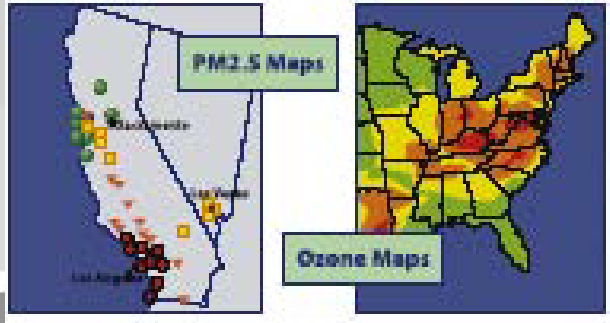
AIRNOW
www.epa.gov

The U.S. EPA has developed the AIRNow website to provide the public with easy access to national air quality information. This website offers daily Air Quality Index forecasts as well as real-time conditions for over 300 cities across the U.S.

Ozone and PM2.5 Forecasts

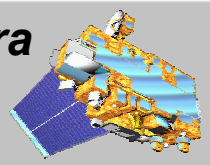


Current Air Quality Conditions

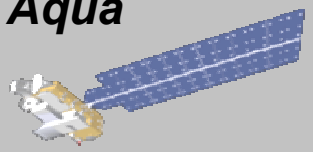


Applying Aerosol Optical Depth for AirNow and Air Quality Forecasting

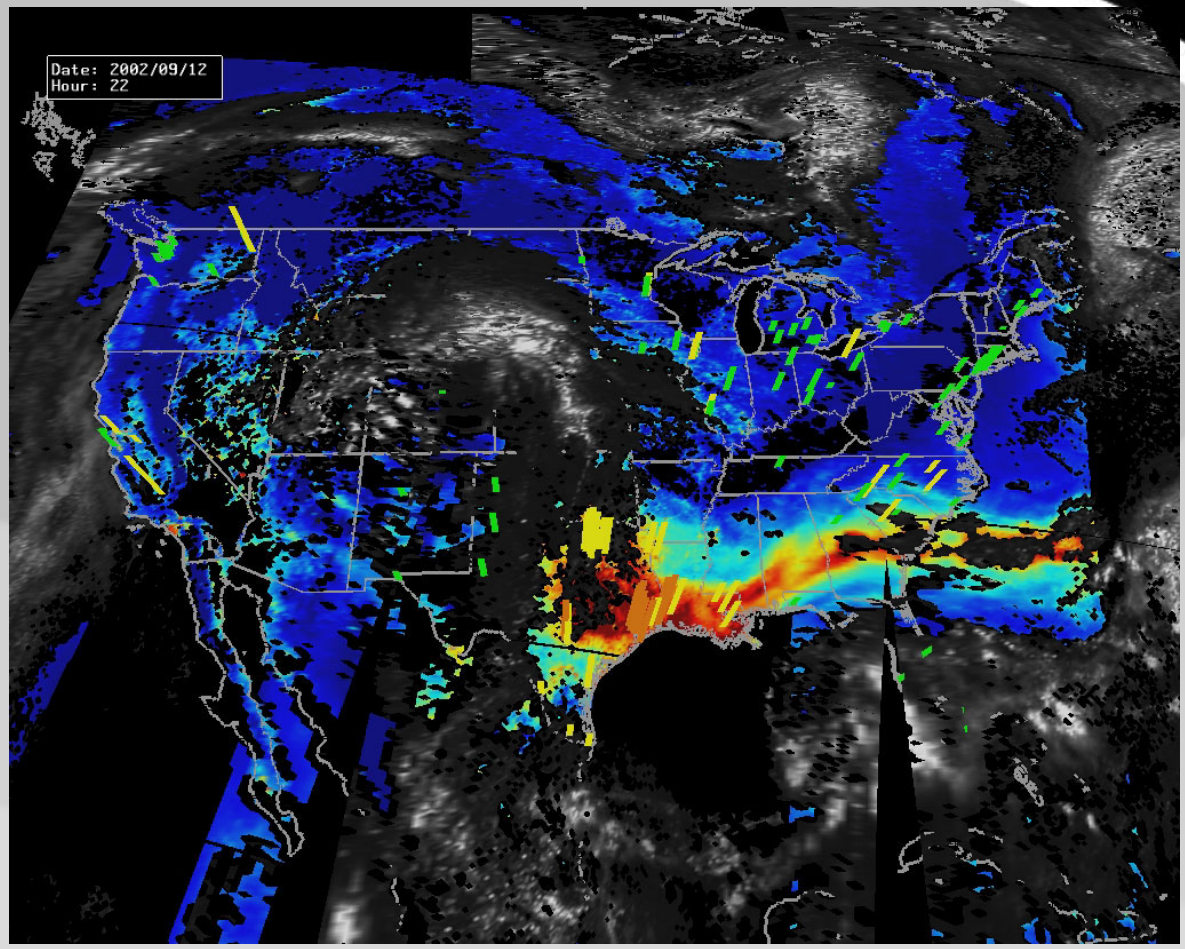
Terra



Aqua



- MODIS Aerosol Optical Depth (AOD) supports EPA/NOAA air quality forecasting & EPA aerosol transport rule making
- Sept. 2003 - successful



MODIS aerosol optical depth & EPA ground measurements of PM2.5.

DEVELOP: Applied Sciences Related to Tennessee Air Quality

Community Concern

- Transportation of tropospheric ozone precursors and particulate matter into the Great Smokey Mountains National Park

Pilot Product

- Visualization using HYSPLIT 4.7 and WinHaze 2.9.6 Models

Customers

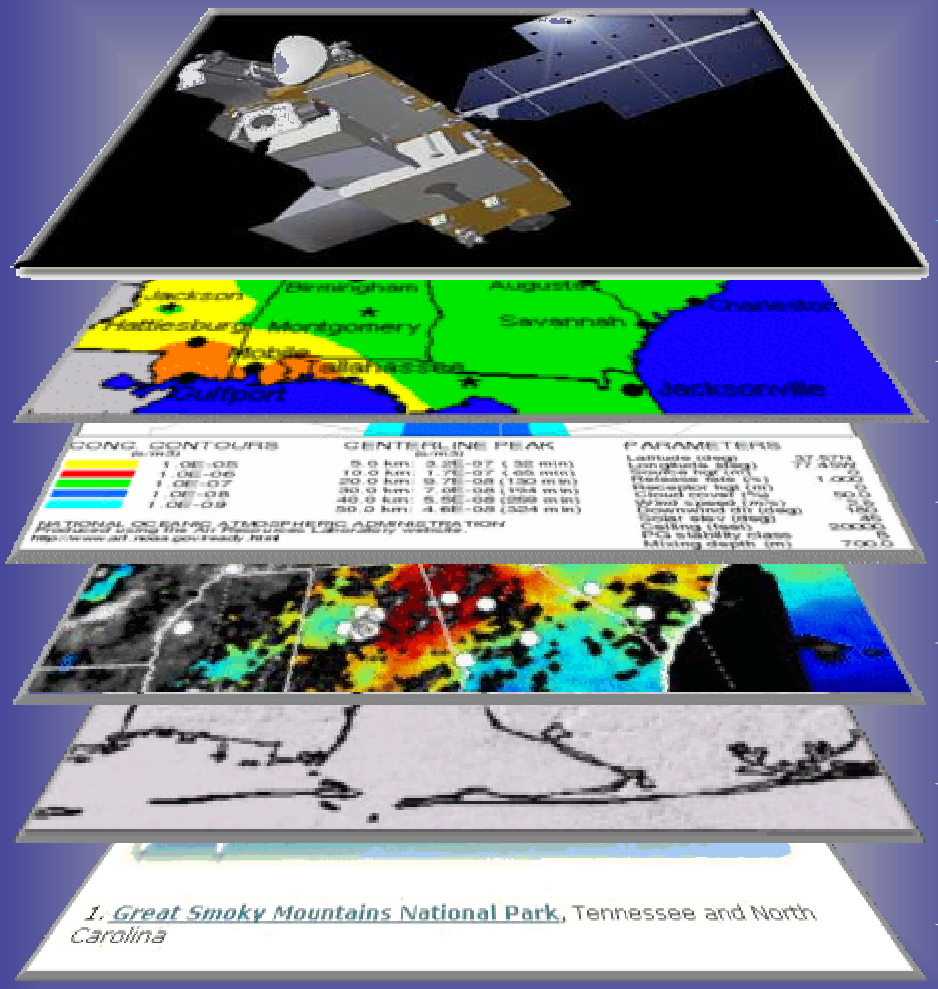
- State of Tennessee
- Tennessee Valley Authority

Science Advisors
Dale Quattrochi, Ph.D
NASA MSFC
Steve Mueller
Tennessee Valley Authority

Public Health

Air Quality

Applied Sciences Related to Tennessee Air Quality



Tropospheric Ozone
Aura (TES and OMI)-NASA

Ozone and PM Measurements
EPA

HYSPLIT 4.7 Output
Trajectory-NOAA

Aerosol Optical Thickness
Terra and Aqua (MODIS)-NASA

Elevation (30 m)
SRTM

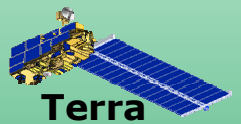
Public Concern-National Park Conservation Association

1. Great Smoky Mountains National Park, Tennessee and North Carolina

Applied Sciences Related to Tennessee Air Quality

Observation Sources

NASA Missions



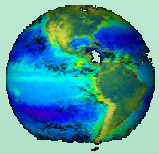
Non-NASA

AQS (EPA)

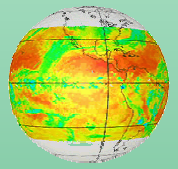
NWS (NOAA)

Land & Atmosphere Data

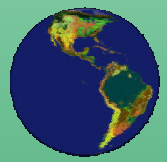
Measurements



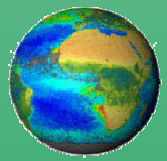
Tropospheric Ozone and Precursors



Atmospheric Temperature



Land Cover/Land Use Inventories



Land Surface Topography

Models

HYSPLIT 4.7

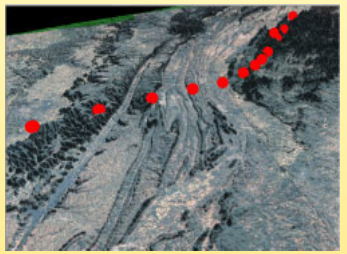
Air Trajectories Modeling

WinHaze 2.9.6

Visual Air Quality Scenes

Model Outputs/Predictions

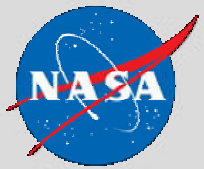
Data Consolidation



Air Parcel Trajectories

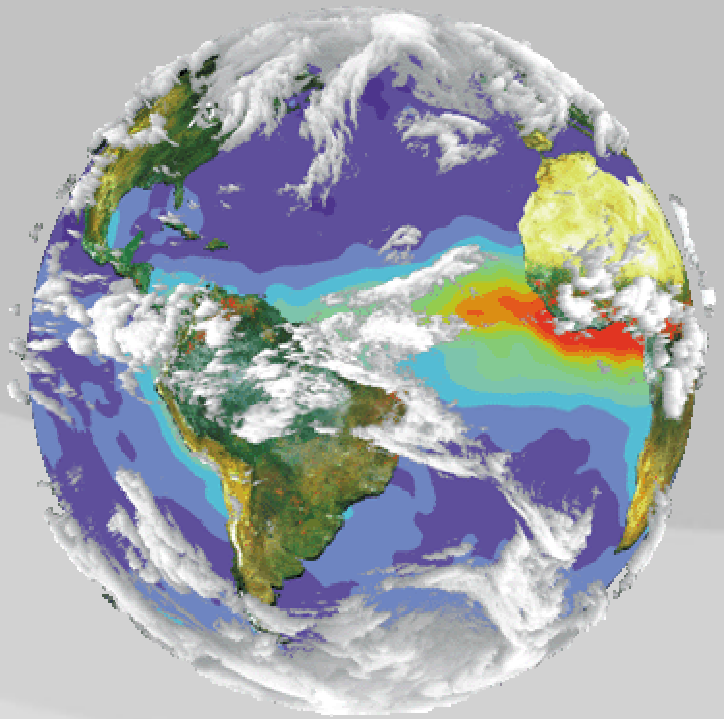
Conclusions

- NASA Earth-Sun Systems data products expanding greatly with the Terra and Aqua platforms (plus others) and improved processing and data distribution tools.
- NASA Applied Science Program concentrating on National Applications in various areas including Energy Management
- These programs are specifically looking for applications of NASA products and capabilities
- Research Announcements and opportunities are being offered to extend the use of the data sets and to expand collaboration with others in government and industry



Planet Earth is a Dynamic System

- Forces acting on the Earth system



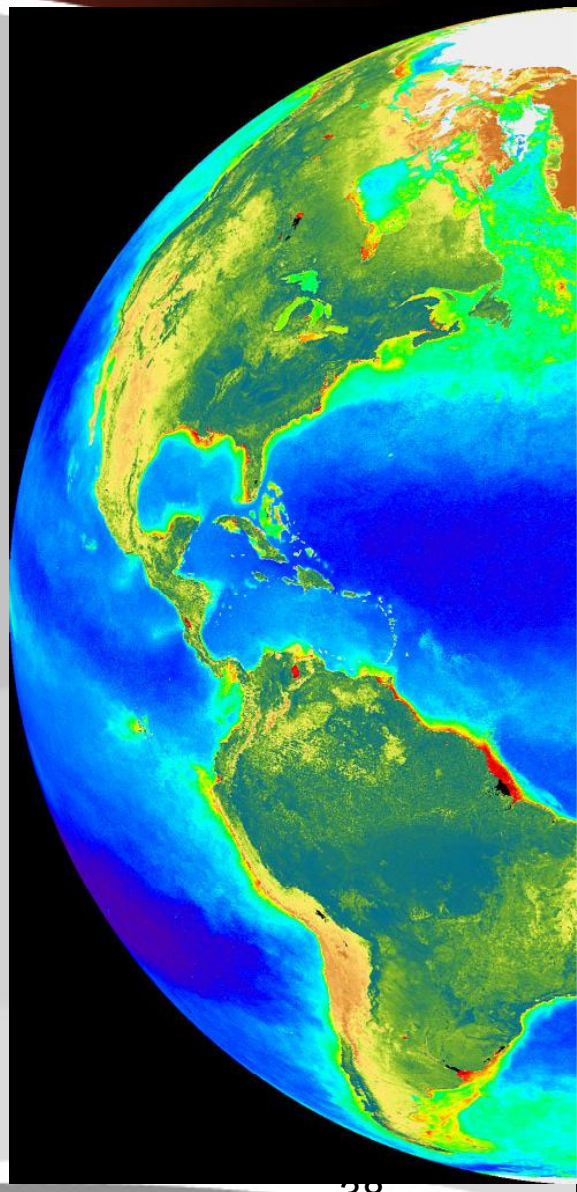
- Earth system responses
- *IMPACTS*

Feedbacks

Earth Science Research Fundamental Science Questions

How is the Earth changing and what are the consequences of life on Earth?

- How is the global Earth system *changing*?
- What are the primary *forcings* of the Earth system?
- How does the Earth system *respond* to natural and human-induced changes?
- What are the *consequences* of changes in the Earth system for human civilization?
- How well can we *predict* future changes in the Earth system?



Science Questions and Focus Areas

Variability	Forcing	Response	Consequence	Prediction
Precipitation, evaporation & cycling of water changing?	Atmospheric constituents & solar radiation on climate?	Clouds & surface hydrological processes on climate?	Weather variation related to climate variation?	Weather forecasting improvement?
Global ocean circulation varying?	Changes in land cover & land use?	Ecosystems, land cover & biogeochemical cycles?	Consequences of land cover & land use change?	Improve prediction of climate variability & change?
Global ecosystems changing?	Motions of the Earth & Earth's interior?	Changes in global ocean circulation?	Coastal region impacts?	Ozone, climate & air quality impacts of atmospheric composition?
Atmospheric composition changing?		Atmospheric trace constituents responses?	Regional air quality impacts?	Carbon cycle & ecosystem change?
Ice cover mass changing?		Sea level affected by Earth system change?		Change in water cycle dynamics?
Earth surface transformation?				Predict & mitigate natural hazards from Earth surface change?

Climate Variability and Change
Atmospheric Composition
Carbon Cycle and Ecosystems
Weather
Water and Energy Cycle
Earth Surface and Interior

Data Acquisition to Data Access

Data Acquisition

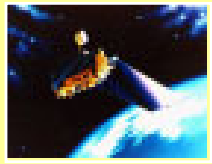
Flight Operations, Data Capture, Initial Processing & Backup Archive

Data Transport to DAACs

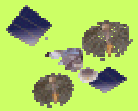
Science Data Processing, Data Mgmt., Data Archive & Distribution

Distribution, Access, Interoperability & Reuse

Spacecraft



Tracking & Data Relay Satellite (TDRS)



Ground Stations

Polar Ground Stations

Data Processing & Mission Control

NASA Integrated Services Network (NISN) Mission Services

EOSDIS Science Data Systems (DAACs)

REASoNs

WWW IP Internet

Science Teams

Measurement Teams

Research

Education

Value-Added Providers

Interagency Data Centers

International Partners

Use in Earth System Models

Benchmarking DSS

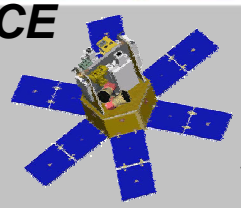
TECHNOLOGY

November 16, 2004

Energy Management

ERBS

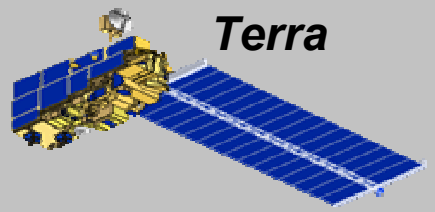
SORCE



Tasking

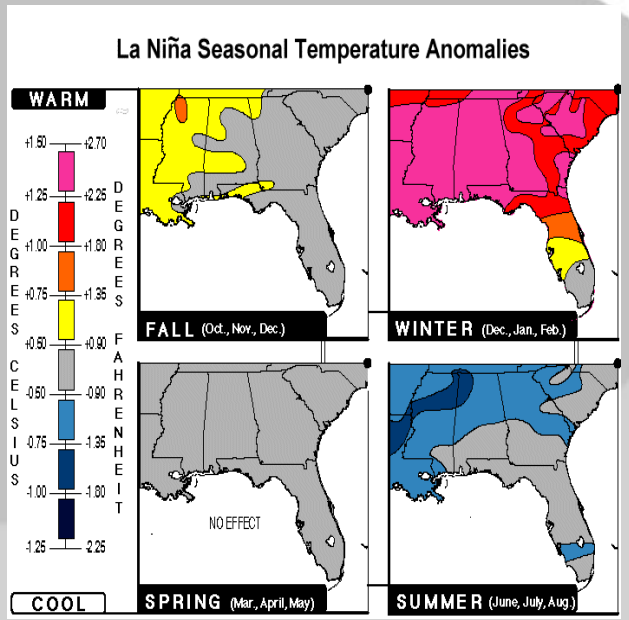
EDOS: Mission Control

Terra



Downlink

Societal Benefits



National Energy Management System

EOSDIS & DAACs

Exploitation